DISCUSSION OF "A KINETIC THEORY OF GRAVITATION."

(Plate I.)

By CHARLES F. BRUSH.

(*Read April 24, 1914.*)

I. Gravitation is Due to Intrinsic Energy of the Ether.

At the Minneapolis meeting of the American Association for the Advancement of Science I had the honor to outline "A Kinetic Theory of Gravitation,"[1] which is in substance briefly as follows:

The ether is assumed to be endowed with vast intrinsic kinetic energy in wave form of some sort capable of motive action on particles, atoms or molecules of matter, and propagated in every conceivable direction so that the wave energy is isotropic. The waves are of such low frequency, or otherwise of such character, that they pass through all bodies without obstruction other than that concerned in gravitation. Distribution of the ether's energy is uniform throughout the universe except as modified by the presence of matter.

Atoms or particles are imagined to be continually buffeted in all directions by the ether waves like particles of a precipitate suspended in turbulent water. There are no collisions because neighboring particles follow very nearly parallel paths.

Each particle or atom of matter is regarded as a center of activity due to its energy of translation initially derived from the ether. There is continual absorption and restitution of the ether's energy, normally equal in amount; but the ether is permanently robbed of as much of its energy as is represented by the mean kinetic energy of the particle or atom. The particle or atom thus has a field of influence extending in all directions, or casts a spherical energy shadow, so to speak, the depth or density of the shadow varying with the inverse square of distance. The energy shadow of a body of matter

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[1] *Science,* March 10, 1911; *Nature,* March 23, 1911.

is the sum of the shadows of its constituent parts. The energy shadows of two gravitating bodies interblend, so that the energy density between them is less than elsewhere, and they are pushed toward each other by the superior energy density, or wave pressure, on the sides turned away from each other.

That the ether really *is* endowed with vast intrinsic energy in some form or forms is the belief of many eminent physicists, and it seems to me highly probable that *all* energy has its source and destination in the ether; that is to say, that energy in all the various forms in which we observe it, comes in some way from the ether and is energy *of* the ether. This view does not in any manner conflict with the principle of conservation of energy.

In support of my contention that etherial energy is the cause and essence of gravitation, I wish to emphasize particularly, what seems to me an obvious fact, that the energy acquired by a falling body comes from the ether, and is restored to the ether when that body undergoes negative gravitational acceleration.

In this connection I cannot do better than quote Lord Kelvin's description of the collision of two very large bodies through the influence of gravitation. In his "Popular Lectures and Addresses" (Vol. 1, 413–417) he says:

"To fix the ideas think of two cool solid globes, each of the same mean density as the earth and half the sun's diameter, given at rest, or nearly at rest, at a distance asunder equal to twice the earth's distance from the sun. They will fall together and collide in exactly half a year. The collision will last for about half an hour, in the course of which they will be transformed into a violently agitated incandescent fluid mass flying outward from the line of motion before the collision and swelling to a bulk several times greater than the sum of the original bulks of the two globes. . . . The time of flying out would probably be less than half a year when the fluid mass must begin to fall in again towards the axis. In something less than a year after the first collision the fluid will again be in a state of maximum crowding towards the center, and this time even more violently agitated than it was immediately after the first collision; and it will again fly outward, but this time axially towards the places whence the two globes fell. It will again fall inwards, and

after a rapidly subsiding series of quicker and quicker oscillations it will subside, probably in the course of two or three years, into a globular star of about the same mass, heat and brightness as our present sun."
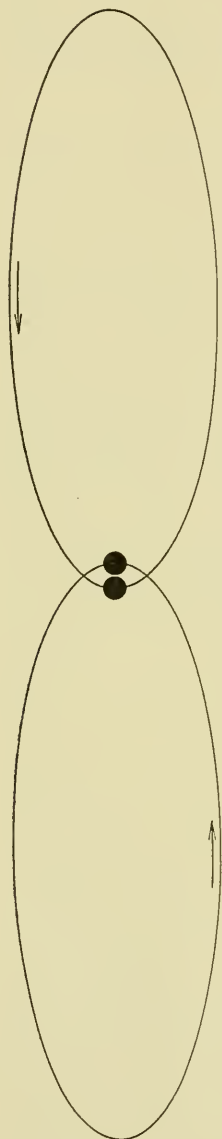
Undoubtedly this is a substantially correct description of what would happen under the conditions named. The two cold bodies would acquire *from some source external to themselves* the vast energy represented by the heat of the sun, heat sufficient to maintain the enormous solar radiation millions of years without sensible diminution. And this vast accumulation of energy would occur in half a year, largely in the *last few days* before collision. There is, to me, no conceivable source of this energy other than the ether. It may be argued that the two cold bodies, as a gravitating system, initially possessed all this energy in the form of "potential energy of position." This is a most convenient expression, but it affords no explanation of the *source* of the energy until, as I pointed out at the Washington meeting, we take the energy-endowed ether into partnership as an essential part of the system. Certainly the energy could not be resident in the two cold motionless globes. For a homely illustration, think of two golf balls joined by a stretched thread of rubber; they form an attracting system and possess "potential energy of position" or separation, but the energy does not reside in the balls, it is in the stretched rubber thread.

Later in his description Lord Kelvin says: "If, instead of being at rest initially, . . . each globe had a transverse velocity of three quarters (or anything more than .71) of a kilometer per second, they would just escape collision, and would revolve in ellipses

Fig. 1.

round their common center of inertia in a period of one year, just grazing each other's surface every time they came to the nearest points of their orbits." (Assuming of course that the globes were sufficiently rigid to escape disruption by tidal forces.)

To aid in forming a mental picture of this last case described by Lord Kelvin, in which the two globes fall together but do not collide, I have made a diagram (Fig. 1) of the two elliptical orbits; and in order to show the globes of appreciable size, the orbits are made very much less excentric than Kelvin's premises call for. The globes are shown at perihelion, just escaping collision. Of course, the globes in falling from aphelion to perihelion would gather the same amount of energy that they did in the case of collision, where their motion was arrested and their kinetic energy was thus converted into heat; but without collision the vast energy acquired during positive acceleration from aphelion to perihelion would disappear during negative acceleration from perihelion to aphelion, and be transformed back to the ether whence it came.

The sun and planets of the solar system, and the planets and their satellites, because of the excentricity of their orbits, continually go through the same kind of cycle described by Lord Kelvin, differing from that only in degree. For instance, the earth in its six months' passage from aphelion to perihelion falls about three million miles toward the sun, and gains in orbital velocity about five eighths of a mile per second. It thus acquires new kinetic energy from the ether which, if it could be manifested as heat, would be sufficient to evaporate all the oceans, lakes, and rivers, heat the dry earth to vivid incandescence, and vaporize much of it; the earth would become a miniature sun. And all this energy is restored to the ether during the next half year while the earth is moving from perihelion to aphelion.

With the idea in mind that a falling body gathers energy from the ether, and restores all of it to the ether when raised the same distance against gravitation, *by any means,* homely examples are at once suggested; thus, a stone thrown upward and falling again, does it in the reverse order, and a common clock pendulum goes through, and repeats the cycle with almost the regularity of a sun and planet.

In the theory of gravitation under discussion, the only new postu-

late is that some or much of the ether's intrinsic energy is *kinetic* and consists of some sort of wave motion or energy flux, whereby a disturbance at any point in the free ether is ultimately felt everywhere else, diminishing in intensity, of course, with the inverse square of distance from the seat of disturbance.

It is not difficult to conceive of kinetic energy in the ether quite apart from matter. Radiation is one form of such energy, and when once launched in the ether it is persistent and quite independent of its source. Interstellar space is alive with wave energy radiated from countless suns, and at points far removed from any single sun this energy is approximately isotropic. Of course this known isotropic wave energy in the ether of space is far too feeble to play any appreciable part in gravitation, and I call attention to it only for the purpose of showing that one sort of free isotropic wave energy in or of the ether in celestial space is already a known phenomenon.

Probably the ether waves concerned in gravitation are not the transverse kind known to us, though it is not difficult to think of transverse waves of great amplitude, embodying great energy, and of such great length that they pass freely through all bodies without appreciably heating them—even electrical conductors. (Incidentally, we cannot be sure that the intrinsic energy of the ether does not impart some low degree of temperature to matter, because we know of nothing in nature at the absolute zero of temperature or anywhere near it.) It seems more likely, however, that the ether waves of gravitation are longitudinal, or otherwise consist in an energy flux which, by reason of its universal presence, has not been made manifest except by gravitation.

It is easy to understand how the supposed spherical field of influence, or energy shadow, surrounding any body of matter may be initiated, but just how it is maintained may never be known; though I hope to have something to say in this connection in a future discussion. But that the field of influence actually *is* maintained seems certain; gravitation itself is a demonstration of it.

The simplest mental picture of the supposed field of influence which I can think of is a spherical energy shadow, and I have endeavored to make this conception visible in Figs. 2 and 3 as light

shadows cast by black spheres. Of course the shadows as here represented are enormously exaggerated. Plate I., Fig. 2, represents a single sphere and the adjacent parts of its spherical shadow. (Obviously a body of *any* shape will cast a shadow substantially spherical.) Plate I., Fig. 3, shows two neighboring spheres with their shadows interblending. The greater depth of shadow between the spheres is clearly indicated, and it is into this deeper shadow that the two gravitating bodies are supposed to be pushed by the superior energy flux from right and left.

Some curious and interesting secondary phenomena are suggested by this conception of the mechanism of gravitation. One of these may be described as follows: Imagine two bodies, such as those of Fig. 1 or Plate I., Fig. 3, falling toward each other by reason of their mutual attraction. They are continually accelerating, and absorbing energy from the ether waves or energy flux pushing them toward each other, whereby these waves pass through and beyond each body *slightly depleted of their energy,* and thus offer less than normal resistance to the advance of the other body; that is to say, the energy shadow between the bodies, into which they are pushed, grows deeper and deeper as they approach, not only because of their lessening distance from each other, but also because of their increasingly rapid transformation of energy as they gain velocity. And it does not matter if the two attracting bodies differ greatly in mass, like the sun and a planet or the earth and a tennis ball, because they will equally acquire momentum, and each will affect the other in the manner described. Stated concisely this means, if my premises are tenable, that Newton's law of inverse squares is not rigidly true for *accelerating* bodies; but that for positively accelerating (approaching) bodies the force of attraction increases a little faster than the inverse square of distance. The force of attraction instead of varying as $1/D^2$ as it does for bodies at rest or in uniform motion, varies as $1/D^{(2-x)}$ for bodies accelerating in the line of attraction, wherein x is a very small quantity which appears to vary with the rate of energy transformation or velocity of fall. When acceleration is negative, that is to say, when energy transformation is *from* the accelerating body *to* the ether, x becomes positive.

Let us consider the effect of x on a planetary orbit: If the orbit is circular, $x = 0$ because there is no change of velocity; but if the orbit is excentric, x obviously grows in value and importance with the excentricity, though always equaling zero at aphelion and perihelion. Fig. 4 illustrates the sun and a planet at aphelion in an ex-
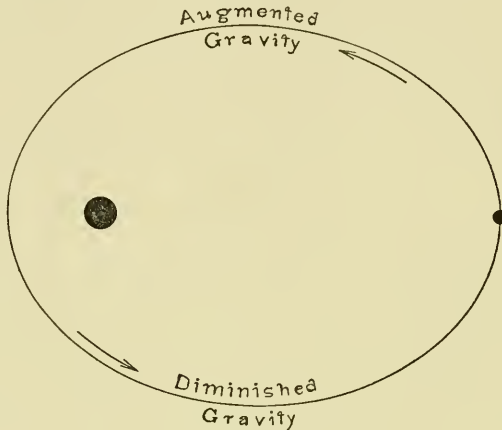

FIG. 4.

aggeratedly excentric orbit. As the planet moves from aphelion to perihelion, normal attraction between the sun and planet is augmented by the positive acceleration of both as before explained; and while the planet moves from perihelion to aphelion normal attraction is diminished by negative acceleration.

If I am not mistaken in my mechanics, the gravitational disturbance above described will slightly change the shape of the orbit, and cause a continual advance in the position of perihelion by advancing the line of apsides. Probably the effect is too small to be detected in the case of any of the planets of the solar system except perhaps Mercury, because of the small excentricity of their orbits; but the high excentricity of Mercury's orbit possibly may reveal it, and I hope it may be found adequate to account for some of the anomalious secular advance of the perihelion of Mercury's orbit. I shall be glad to have my astronomical friends investigate this.

The orbit of the moon is not very excentric, but she moves toward and away from the sun almost the full diameter of her orbit

every month. Perhaps the gravitational disturbance I have suggested may aid in explaining some of her more obscure motions; and I hope it will be found to have a slight accelerating tendency so as to compensate the slight retarding tendency of which I shall treat in the second division of this paper.

2. Transmission of Gravitation Cannot be Instantaneous.

Laplace at first sought to explain the secular acceleration of the moon's mean motion by ascribing to gravitation a finite velocity of propagation. Later he said:[2] "The time of its transmission, if it were sensible to us, would be particularly evinced in the acceleration of the moon's motion. I suggested this as a means of explaining the acceleration which is observed in this motion; and I have found that in order to satisfy observations we must ascribe to the force of gravity, a velocity seven millions of times greater than that of a ray of light. As the cause of the secular equation of the moon (c) is now well understood, we may affirm that the attraction is transmitted fifty millions of times more rapidly than light. We can therefore assume, without any apprehension of error, that its transmission is instantaneous."

I doubt if anyone who has bestowed careful thought on the subject, in the light of present-day physics, really believes this. To me, it is inconceivable that my change of position, as I walk across a room, is felt among the fixed stars while I am still walking; but the justly great name and fame of Laplace has stamped this dogma with the seal of authority, and for more than a century it has blocked the path of fruitful thought on the physics of gravitation.

Doubtless Laplace made no serious mathematical mistake in reaching his remarkable conclusion, but perhaps he erred in his choice of premises. He postulated[3] a "force" or "gravific fluid," "which rushes towards the sun with an immense rapidity; the resistance which the planet experiences from this current in the direction of the tangent, he conceives to produce a perturbation in the elliptic motion, like to the aberration of light." He then applied this

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[2] "System of the World," Harte's translation, Vol. 2, p. 322.
[3] Harte's translation, Vol. 2, notes, p. 490.

conception to the case of the earth and moon. I have endeavored
to visualize Laplace's conception in Fig. 5, in which E represents the
earth, M the moon moving in the dotted line orbit in the direction
indicated by the large arrow, and lines NE the " gravific fluid " rush-
ing from all directions toward the earth. The orbital motion of the
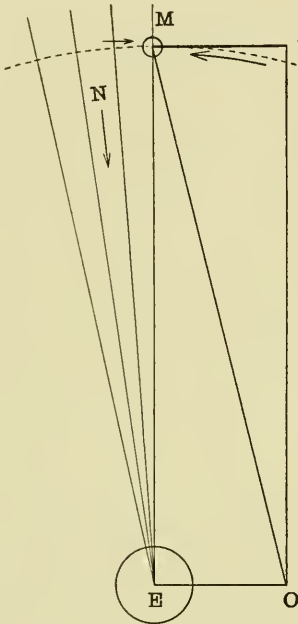moon continually carries her laterally against the stream of "gravific
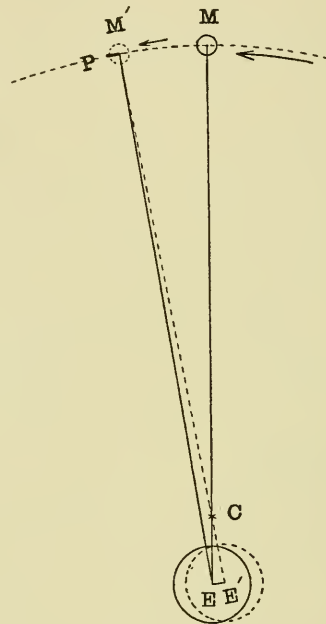

Fig. 5.   Fig. 6.

fluid," whereby she experiences a tangential retarding force, indi-
cated by the small arrow, just as if a less rapid flow of "gravific
fluid " came from that direction. Let the line MP represent the
direction and value of the retarding force in terms of the centripetal
force ME. Completing the parallelogram of forces, we find the line
of the moon's attraction shifted from ME to MO. Clearly this
would result in the moon taking an orbit in the form of a contract-
ing spiral which would ultimately bring her to the earth. At the
same time her actual velocity would continually increase (and her
angular velocity still more so) because of her falling toward the

earth; gravity directly, and the retarding force indirectly conspiring toward this result. With the assumed velocity of light for the " gravific fluid," Laplace found that the angular acceleration of the moon's motion would be millions of times greater than necessary to account for her known acceleration.

I have thus outlined Laplace's conception of the mechanism of gravitation, which led to his famous conclusion of virtually infinite velocity of propagation, because I have not met with anything of the sort in modern text books of astronomy or physics; his startling conclusion is known to everyone, but his premises are generally forgotten; and further because I wish to have it clearly in mind for contrast with what is to follow.

Returning now to the theory of gravitation under discussion: In Fig. 6, E represents the earth and M the moon moving in the dotted line orbit in the direction indicated by the large arrow, both revolving about their common center of gravity C. Instead of showing C well inside the earth's circumference where it belongs, I have shown it outside, so as to enlarge certain details of the diagram and thus avoid confusion of lines.

The earth and moon are each supposed to cast a spherical energy shadow, or occupy the center of a spherical field of influence, as already indicated, into which the other is pushed by the slightly superior energy-flux coming from beyond it. The strongest push of each is toward the densest part or *origin* of the shadow of the other. Thus, if earth and moon were stationary, each would be pushed toward the center of mass of the other. But while the shadow, emanating so to speak, from the earth at any instant is being propagated outward to the moon's orbit, the latter will have moved to M', and the earth will have moved to E'. Clearly then, the moon at M' will not be pushed toward E', but toward E, which is the origin of the shadow into which it is being pushed. The centripetal force $M'E$ may be resolved into the radial component $M'E'$ and the tangential component $M'P$ equal to the displacement of the earth's center from E to E'. Clearly, the force $M'P$ is an *accelerating* force, and bears the same ratio to gravity at M' that $M'P$ bears to $M'E'$.

If the velocity of propagation of the energy shadow equals the

velocity of light, then the displacement of the earth's center from E to E' will be about 52 feet, and the tangential force $M'P$ will be about one twenty-four-millionth of gravity at the distance of the moon.

Obviously, this very small tangential force will tend to make the moon's orbit an expanding spiral of very small pitch; but the vastly greater force of gravity will resist this tendency and nearly, but not quite, counteract it; the net effect being an extremely slow lengthening of the radius vector, and a very slight *retardation* of real as well as angular velocity. This paradoxical effect, of an accelerating force producing an orbital retardation, is explained by Sir George H. Darwin in his chapter on tidal friction and the genesis of the moon.[4]

I have made only a very rough estimate of the secular retardation of the moon's mean motion which this minute accelerating force will bring about, with gravitational transmission taken equal to the velocity of light, but have satisfied myself that it will amount to a very few seconds of arc only, in a century; and I do not claim that the velocity of light is the velocity of gravitational propagation unless the postulated ether waves are ultimately found to be transverse like those of radiation. I think it probable that they are longitudinal, or otherwise different from those of radiation. If this be true, the velocity of propagation may be several times greater than that of light, and the secular retardation of the moon correspondingly less.

I realize that any uncompensated retardation of the moon's motion will add to the present outstanding observed acceleration, if any; but am hopeful that the slight departure from Newton's law of inverse squares already suggested may, in connection with other motions of the moon, supply some of the necessary compensation. There is also a minute source of compensation, due to motion through the ether, which I intend to consider in another discussion.

CLEVELAND,
    April, 1914.

[4] "The Tides," Chap. XVI.